

Principles of Flight

Principles of Flight – Study Notes

1. Overview

The ability of an aircraft to become airborne and stay aloft depends on four fundamental aerodynamic forces and the physical principles that generate them. Understanding these forces, how they interact, and the governing equations is essential for pilots, engineers, and anyone studying aeronautics.

2. The Four Aerodynamic Forces

Force	Direction	Primary Source	Key Factors
Lift	Perpendicular to the oncoming airflow (upward for conventional aircraft)	Pressure differential over the wing (Bernoulli & Newton)	Wing shape, angle of attack, airspeed, air density, wing area
Weight (Gravity)	Vertically downward	Mass of the aircraft and payload	Aircraft mass, fuel consumption (changes over time)
Thrust	Parallel to the flight path (forward)	Propulsion system (engine, propeller, jet)	Engine power, propeller pitch, exhaust velocity
Drag	Opposite to the direction of motion	Friction and pressure forces on the aircraft's surface	Shape, surface roughness, speed, Reynolds number

Equilibrium for steady, level flight:

Lift = Weight and Thrust = Drag

3. How Lift Is Produced

3.1 Bernoulli's Principle

Principles of Flight

- Faster airflow over the wing's upper surface creates lower pressure.
- Pressure difference (Δp) multiplied by wing area (S) yields lift:
[$L = \Delta p \times S$]

3.2 Newton's Third Law (Action–Reaction)

- Air is deflected downward by the wing; the reaction force pushes the wing upward.
- The **downwash** angle relates to lift magnitude.

3.3 The Lift Equation

$$[L = C_L ; \frac{1}{2} \rho V^2 S]$$

- (**C_L**) – Lift coefficient (function of airfoil shape & angle of attack)
- (**ρ**) – Air density (altitude, temperature, humidity)
- (**V**) – True airspeed relative to the wing
- (**S**) – Wing planform area

Implication: Doubling speed quadruples lift (since (V^2) term).

4. Angle of Attack (AoA)

- **Definition:** Angle between the chord line of the wing and the relative wind.
- **Effect on (C_L):** Increases roughly linearly up to the **stall angle** (~15° for many airfoils).
- **Stall:** Beyond the critical AoA, flow separates, (C_L) drops sharply, and drag rises.

Key point: Lift depends more on AoA than on speed for a given airfoil; pilots control AoA with pitch attitude and trim.

5. Drag Components

Type	Description	Dependence
Parasite Drag	Skin friction + form drag + interference drag	Increases with (V^2)

Principles of Flight

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Induced Drag	Result of lift creation (vortices at wingtips)	Inversely proportional to (V^2) (dominant at low speeds)
Wave Drag (high speed)	Shock waves when approaching/supersonic	Appears near Mach 0.8–1.2

Total Drag:

$$[D = D_{\text{parasite}} + D_{\text{induced}} + D_{\text{wave}}]$$

6. Thrust and Propulsion